RISCAuthority

administered by FPA Fire Protection Association

RC65: Recommendations for fire safety with 3D printing

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Summary of Key Points

The table below summarises the key points of the document.

Select the most appropriate equipment to purchase	• Prior to purchase consider criteria such as the choice of material(s) to be used, production cycle times, speed of production and post-production processing and costs (1.2)
Understand the process	• Understand the way that the equipment operates and the facilities that need to be provided to allow fire hazards to be adequately assessed, and appropriate protection measures identified (5.3.1)
Maintain business continuity	• Hold duplicate copies of computer software, CAD or 3D modelling files that drive the printers off site in case of fire, flood or other emergency (5.2.2)
Avoid leaving the printing process unattended until proven to be reliable	• Before being left unattended, a new 3D printing process should be fully developed and run for a prolonged period with staff in attendance (5.3.5)
Assess the process before unattended operation	• If it is intended that equipment is to be left operating without staff in attendance, then a specific risk assessment for the process should be undertaken and appropriate control measures introduced (5.2.3)
Provide environmental controls where necessary	• Some 3D printing processes are carried out in controlled atmospheres. Measures for monitoring and controlling the composition of the atmosphere should be planned and put in place (5.3.1)

Symbols used in this guide

Good practice

Bad practice

Discussion topic

FAQ Frequently asked question

1 Introduction

How may a fire originate in a 3D process that is allowed to operate unattended?

3D printing has come of age remarkably quickly. A few years ago it was only considered for concept models and prototypes, whereas it is now used daily in routine manufacturing processes.

Whereas traditional manufacturing processes were based on casting, moulding or subtractive technologies, 3D printing is a creative approach based on the incremental addition of layers of material by a process (additive manufacturing) allied to printing but using a variety of materials in place of ink, which results in the formation of a three dimensional object in a single process. At the heart of the process is a computer using data originating from CAD drawings, 3D scanners or 3D modeling software which controls the laying down of the layers of material. For some medical products the data may originate from MRI scanners and similar sources.

Since the first prototype printers were manufactured in the mid-1980s, developments have been rapid, with printers using such diverse materials as plastics, polymers, wax, glass, metal, sand and glue mixtures, edible food and human tissue. Fire resistant products for use in the aerospace industry may also be manufactured using 3D printing technologies. There are many forms of printers which, due to the differences in the properties of the materials that they employ, may introduce a variety of fire hazards into the workplace. Because of this, and the continuing rapid development of the process, the recommendations that follow reflect somewhat a snapshot in time and should be interpreted in the light of the specific processes and materials employed in the workplace.

The wide range of products that can be manufactured on site by a 3D printing process may – in the near future – have a significant impact on the volumes and nature of stored materials in some factories and warehouses. Although this may result in the reduction of some fire hazards, new and novel hazards may be introduced in their place.

1.1 The technology

Three dimensional representations of an object may be formed from designs produced by CAD software or by scanning an existing object. This data may then be used to control a 3D printing process which is akin to a conventional printer, but builds up layers of substrate one on top of another, until a reproduction of the object is formed in the substrate material. The accuracy of the 3D image is dependent on the quality of the information provided by the CAD software or scanning technique. Printers are available that can print using plastics, metals, food and organic materials.

While the first printers built in the 1970 were large – and being prototypes were expensive – modern printers are available that sit on a desktop and are even suitable for use in the home.

While most printers create plastic parts using hot plastic, plastic powder-based technologies can also generate thermoplastic parts in a range of engineered production plastics such as polyamide, as well as being used to produce heat resistant materials. When printing with metal the particle size that is utilised is especially critical, as it directly influences the part density as well as the accuracy, surface quality and feature resolution.

Not all 3D printers use the same technology. There are several ways to print, but all are additive, differing in the way layers are built to create the final object. Some methods use melted or soft material to produce the layers: selective laser sintering (SLS) and fused deposition modeling (FDM) are the most common of these technologies. Another method involves curing a photo-reactive resin with a UV laser or similar power source one layer at a time. The most common technology using this method is called stereolithography (SLA).

The American Society for Testing and Materials (ASTM) has developed a series of standards (see further reading) that classifies additive manufacturing processes under seven headings:

1.1.1 Vat photopolymerisation

The most commonly used, but not the only technology employed in this process, is Stereolithography (SLA). This technology uses a vat of liquid ultraviolet curable photopolymer resin and an ultraviolet laser to build the object's layers one at a time. For each layer, the laser beam traces a cross-section of the part pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern traced on the resin, prior to a platform descending by an incremental distance and the process being repeated continuously to create a large number of joined layers.

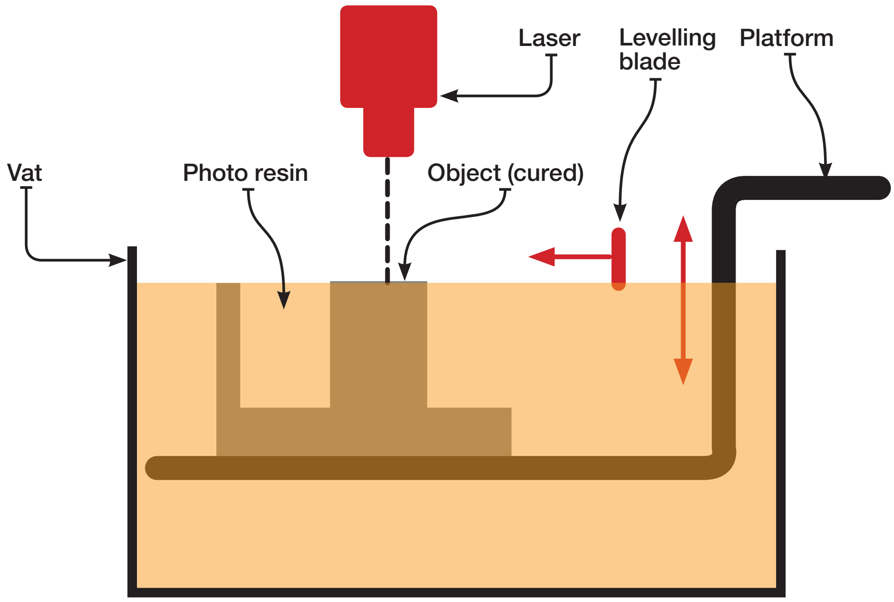

Figure 1: Vat photopolymerisation

1.1.2 Material jetting

This is the process most akin to conventional printing. Material is applied in droplets through a small diameter nozzle in a similar way to an inkjet paper printer, but it is applied layer-by-layer to a build platform, making a 3D object which may then be cured by UV light.

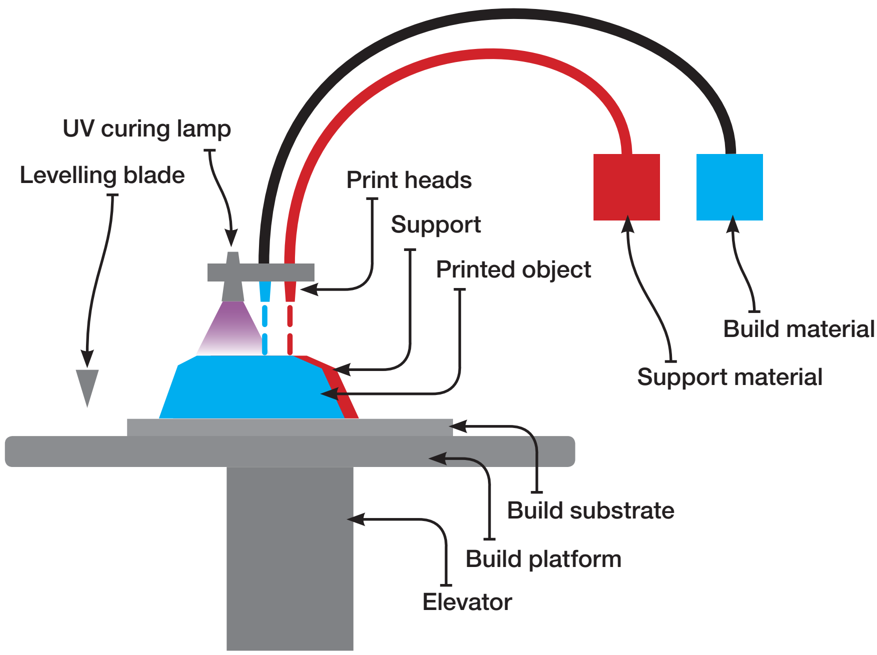

Figure 2: Material jetting

1.1.3 Binder jetting

Two materials are used in this process, a powder base material and a liquid binder. Powder is spread in a powder bed build chamber in sequential layers followed by a binder which is applied through jet nozzles. The programming of the nozzles and lowering of the powder bed has the action of building up the shape of a programmed 3D object. After the print is finished, the remaining powder is cleaned off and may be reused for printing the next object.

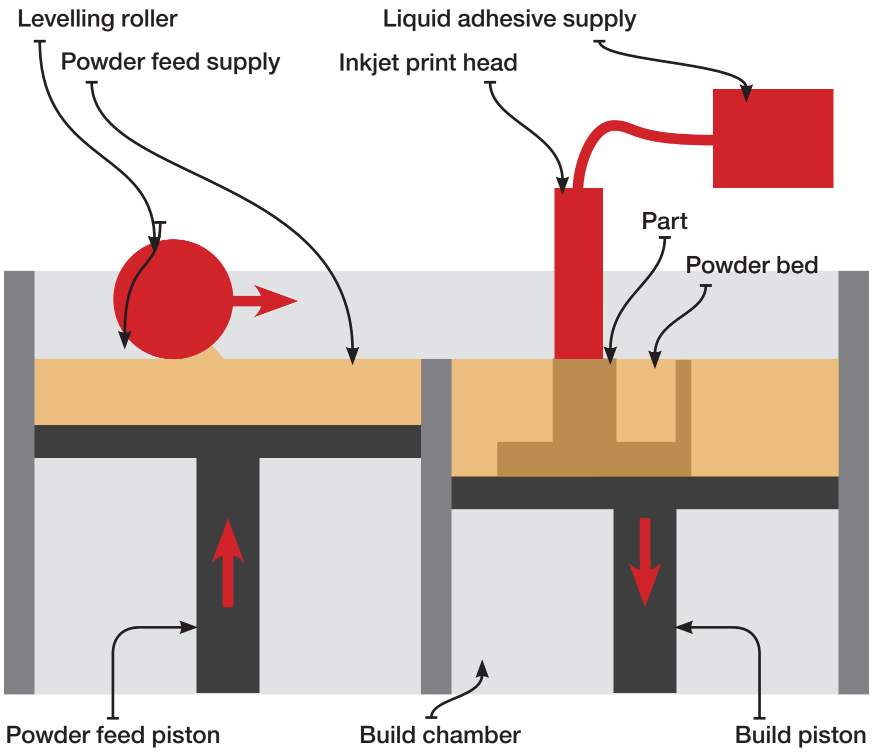

Figure 3: Binder jetting

What is the most appropriate fire protection system for my 3D printing enclosure?

1.1.4 Material extrusion

The most commonly used technology in this process is fused deposition modeling (this term and its abbreviation FDM are registered trademarks). FDM technology uses a plastic filament or metal wire, which is unwound from a coil and supplies material to a controllable extrusion nozzle. The nozzle is heated to melt the material, and can be moved both horizontally and vertically by a mechanism directly controlled by a computer-aided manufacturing software package. The extruding material forms layers as it hardens immediately after deposition from the nozzle. This technology is most widely used with two plastic filament material types, ABS (acrylonitrile butadiene styrene) and PLA (polylactic acid), but many other materials are available (including nylon, thermoplastic polurethane and polycarbonate), allowing the manufactured object to have various physical properties.

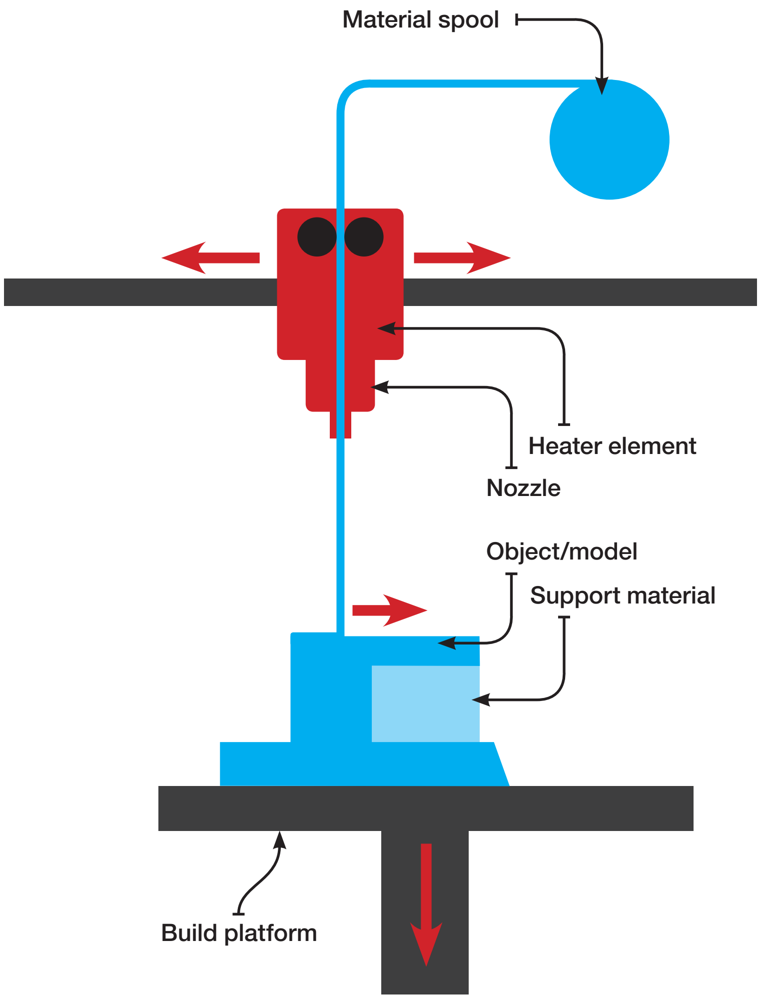

Figure 4: Material extrusion

1.1.5 Powder bed fusion

The most commonly used technology in this process is selective laser sintering (SLS). The process uses a high-power laser to fuse small particles of plastic, metal, ceramic or glass powders into a mass that has the desired three dimensional shape. The laser selectively fuses the powdered material on the surface of a powder bed by scanning the cross-sections (or layers) generated by a 3D modelling program. After each cross-section is scanned, the powder bed is lowered by one layer thickness, and the process is repeated until the object is complete.

The unfused powder acts as a support for the object being created and thus no further support is required. All unused powder can be used for the next print.

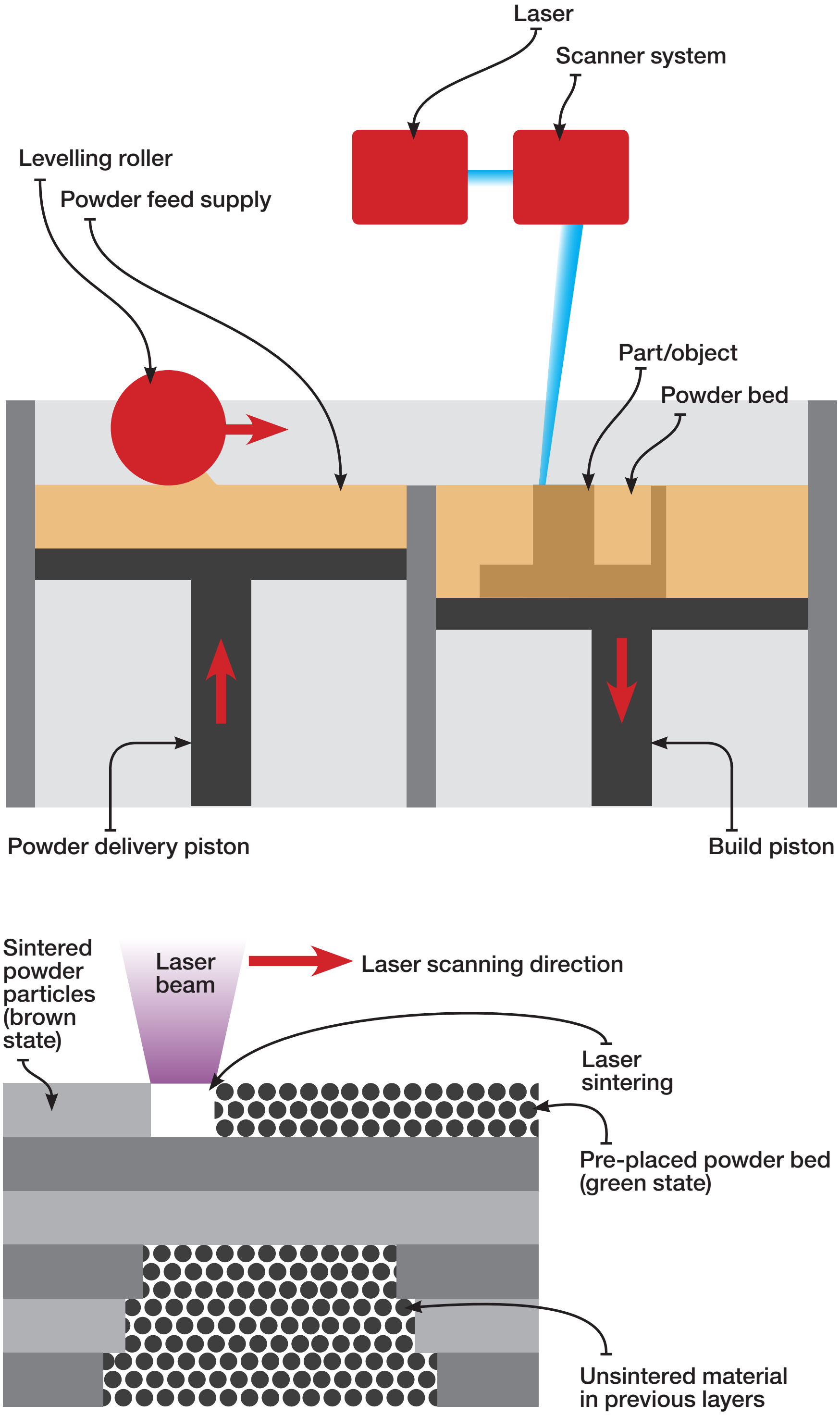

Figure 5: Selective laser sintering

1.1.6 Sheet lamination

Although classified as an additive technology, this is a quite different process which may not be considered to be printing. Sheet lamination involves material in sheets bound together with external force. Sheets can be metal, paper or a form of polymer. Metal sheets are welded together by ultrasonic welding in layers and then milled into a proper shape. Paper sheets can also be used, but they are glued by adhesive glue and cut into shape by precise blades.

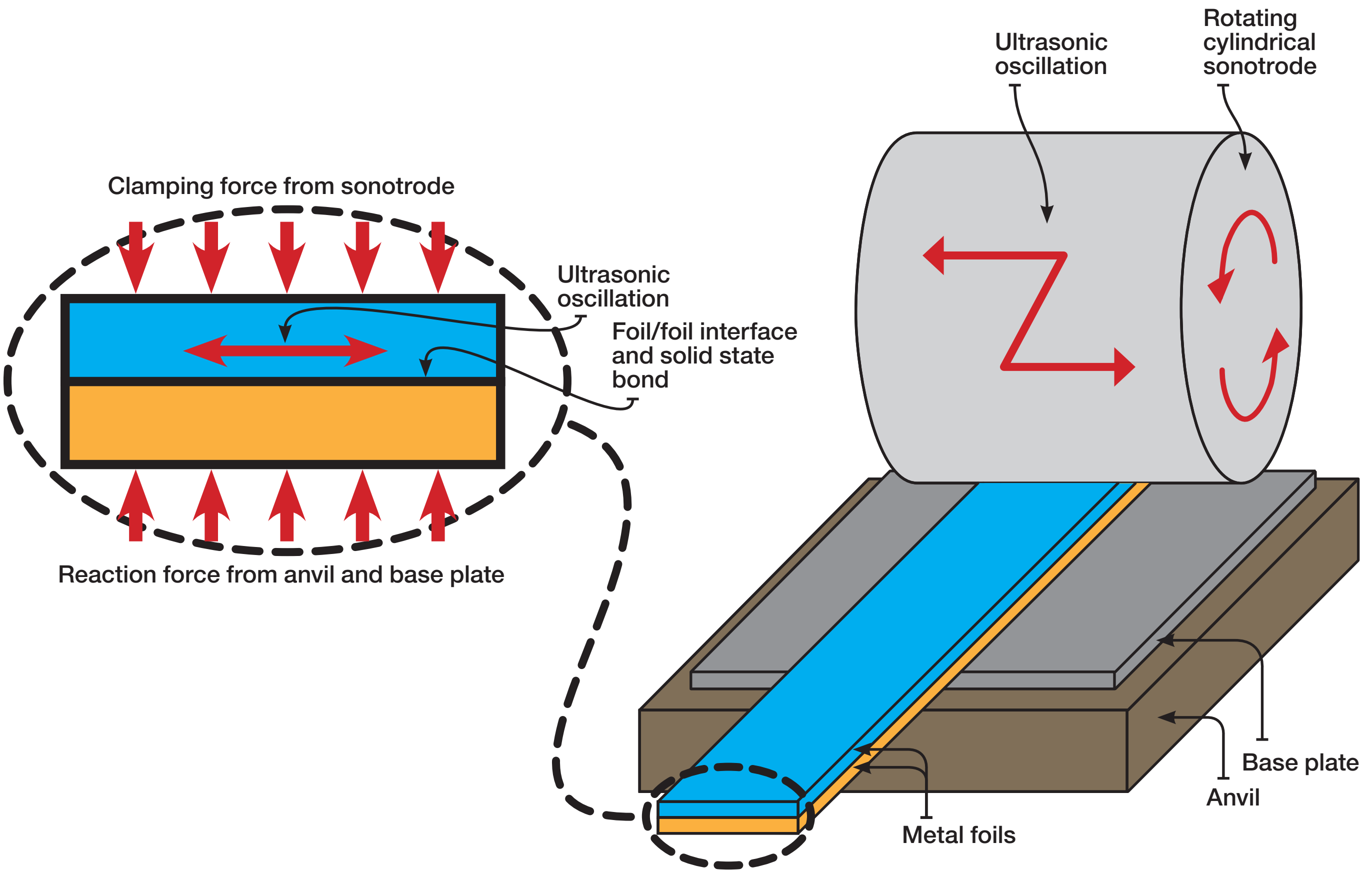

Figure 6: Sheet lamination

1.1.7 Directed energy deposition

This process is an elaborate technology, mostly used in the high-tech metal industry and in rapid manufacturing applications. The 3D printing apparatus is usually attached to a multi-axis robotic arm, and consists of a nozzle that deposits metal powder or wire on a surface and an energy source such as a laser, electron beam or plasma arc that melts it, forming a solid object.

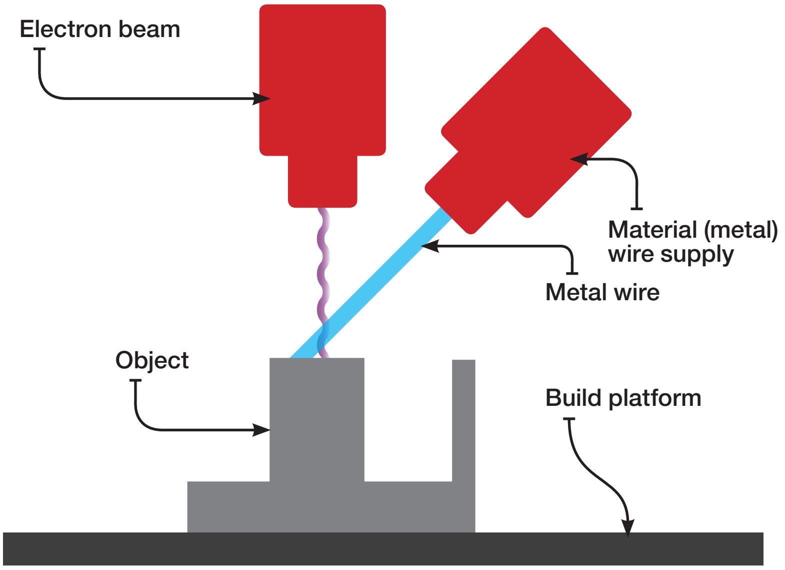

Figure 7: Directed energy deposition printing

1.2 Selecting the process

Prior to considering which technology to employ, criteria such as the choice of material(s) to be used need to be considered, together with production cycle times, the speed of production, any post-production processing and costs. Specialist advice may be needed as part of this process.

The main variable is the 'speed' of printing, but this may have several definitions. Often considered simply as the vertical build speed, an alternative approach is to consider the time required to build a specific part or to print a specific volume. This may be important where a technology that may print a single, geometrically simple part quite quickly slows down when additional parts are added to a print job, or when the complexity and/or size of the geometry increases.

Each 3D printing technology requires a different level of post-processing once the parts have been printed, although some of these steps can be automated. Powder-based technologies tend to require the least post-processing as they only need to be de-powdered, and no supports or supporting materials have to be removed. On the other hand, some plastic 3D printed parts may require processes such as rinsing, UV curing and the removal of manual supports.

Other criteria that have to be considered include the maximum size of the product that can be produced by the equipment, and the ability to produce coloured objects, when the ability to dither colour information may be the defining factor in the choice of product.

2 Scope

These recommendations have been produced to minimise the likelihood and consequences of a fire involving a 3D printer in commerce and industry. The term 3D printing relates to a wide range of processes using diverse equipment and a broad spectrum of applied materials. The advice is not intended to apply to 3D printing undertaken in a domestic environment.

3 Synopsis

3D printing technologies are becoming increasingly utilised in industry. These recommendations are not directed to any industrial sector and are concerned with the need for 3D printers to operate in a fire safe environment, whether it is permanently attended or being left unattended due to the length of time required to build a large object.

The recommendations in this publication present guidance for fire safety when using three dimensional (3D) printers; because of the rapidly developing and increasingly diverse nature of the processes employed, the guidance is of necessity of a general nature. The recommendations should be applied in conjunction with the manufacturer's instructions and the fire risk assessment for the premises.

4 Definitions

Unattended process

An unattended process is one that, once set up, is required to continue for a prolonged period of time without intervention or periodic monitoring by personnel.

Dither

Dithering is the attempt by a computer program to approximate a colour from a mixture of other colours when the required colour is not available.

5 Recommendations

FAQ

What actions can be taken to maintain business continuity in the event of a fire where a 3D printer is being used?

5.1 Compliance with fire safety legislation

5.1.1 A suitable and sufficient fire risk assessment should be undertaken for all premises to which the Regulatory Reform (Fire Safety) Order 2005 (or equivalent legislation in Scotland and Northern Ireland) applies (refs 1-5).

5.1.2 The potential hazards associated with 3D printing processes should be considered when undertaking assessments in compliance with the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR (as amended 2015) (ref. 6). DSEAR assessments should be undertaken by a competent person.

5.1.3 Risk assessments should be subject to periodic review, including at the time when any changes to the machinery, plant or materials being employed in the printing process or in the layout of the workplace are being considered.

Duplicate copies of the CAD or 3D modelling files should be available off site in case of fire or flood at the workplace

5.2 Business continuity

5.2.1 Even a small fire can have a disproportionate effect on a business if it occurs in a critical area. The 3D printing process must therefore be carefully managed to avoid unnecessary disruption to the efficient functioning of the business.

5.2.2 It is important that the computer software, CAD or 3D modelling files that drive the printers are duplicated off-site together with other company records, so that the electronic instructions for the printers are not lost in the event of fire. Software files that form off-site back ups should be tested to ensure that they can be recovered from the archive to operate the printer. Primary samples of products should also be kept off site to allow them to be available for scanning if necessary.

5.2.3 All businesses should take steps to maintain the continuity of their operations by making a suitable emergency plan. Guidance for this is set out in Business resilience: A guide to protecting your business and its people (ref 7). The emergency plan should address the implications of a fire, flood or other perceived disaster on all facets of the business model. It should indicate the lines of communication that should be followed and the contact details for specialist assistance, providers of alternative accommodation and suppliers of replacement 3D printing and other equipment.

5.2.4 Tabletop exercises should be held periodically to test the effectiveness and suitability of the emergency plan.

5.2.5 Consideration may be given to applying commercially available computer programs such as the ROBUST software (Resilient Business Software Toolkit) that is available free of charge (ref 8), or similar, to develop and check the adequacy of the plan.

5.2.6 Where parts are purchased that are known to be produced by 3D printing then the organisation's emergency plan should identify alternative suppliers. It should be recognised that there may be limited alternative sources, and complications may arise due to possible legal protection of the printing programme or process. Supplies may also be dependent on the fire safety management regime of the supplying company.

When considering purchasing 3D printing facilities ensure that the most appropriate equipment is purchased, and the fire hazards that are introduced into the workplace are adequately assessed

5.3 Fire safety management

5.3.1 There are a wide range of 3D printers available utilising different modes of operation and materials. Care should be taken when considering purchasing 3D printing facilities that the most appropriate equipment is purchased. The way that the equipment operates and the facilities that need to be provided should be fully understood, to allow fire hazards that are introduced into the workplace to be adequately assessed, and appropriate prevention and protection measures identified and implemented where necessary.

5.3.2 Any areas of heat production in the process should be identified to allow safety controls, including thermostats and upper temperature limit temperature sensors, to be identified and put in place.

5.3.3 The response by fire and rescue services to 999/112 calls and signals routed via fire alarm monitoring organisations varies widely throughout the UK, and differs from day to night-time. Fire safety managers should refer to the relevant fire and rescue service to make themselves aware of the levels of response in the areas in which their premises are located, and consider this information when undertaking and reviewing their fire risk assessments.

3D printers should not be allowed to operate unattended without the process being fully developed and run for a prolonged period of time with staff in attendance

5.3.4 Site plans should be available for the emergency services: these should show the locations of the printing equipment and associated installations, and any other relevant fire hazards such as flammable liquid or compressed gas stores.

5.3.5 Unattended operation of 3D printers should be avoided where possible. Where this is not practicable, new 3D printing processes should be fully developed and run for a prolonged period with staff in attendance prior to the possibility of unattended operation being assessed. This is to ensure that the equipment is working satisfactorily, and that all foreseeable potential safety issues and fire hazards have been identified and addressed.

The use of flammable liquids as part of 3D printing processes or for maintenance purposes should be avoided

5.3.6 In commercial premises where 3D printing is undertaken, the fire hazards and thus the threat to the business are increased if the processes are allowed to continue unattended. If it is intended that equipment is to be left operating without staff in attendance, then a specific risk assessment for the process should be undertaken and appropriate control measures introduced. Further information regarding unattended processes is set out in RC42: Recommendations for fire safety of unattended processes (ref 9).

5.3.7 Where equipment is left to run, unattended notices should be displayed prominently outside the door(s) to the compartment in which the process is located, giving the contact details of staff who should be contacted in an emergency.

5.3.8 The fire risk assessment undertaken during the planning stage should consider the nature of the materials used in the process; any powders, flammable liquids or other hazardous materials should be identified to allow suitable measures to be adopted for their safe storage, handling and use.

5.3.9 Where powders are used in the process, as a powder bed or a support material, the guidance presented in RC12: Recommendations for the prevention and control of dust explosions (ref 10) should be observed. In particular, care must be taken to avoid disturbing powder beds that could form dispersions of powder in the air.

5.3.10 The use of flammable liquids should be avoided wherever possible. Where this is unavoidable as part of a process or for servicing and maintenance purposes, the minimum quantities consistent with effective working should be introduced into the building. Flammable liquids should be stored, handled and used in accordance with the guidance set out in RC55: Recommendations for fire safety in the storage, handling and use of flammable and highly flammable liquids (ref 11).

5.3.11 Any spillage of flammable liquid should be addressed immediately using suitable absorbent materials. The process may have to be halted in the event of a significant spillage.

5.3.12 Some 3D printing processes are carried out in controlled atmospheres. Measures for monitoring and controlling the gas supply and composition of the atmosphere should be planned and put in place. The storage, use and handling of gases in cylinders should be in accordance with the recommendations set out in RC8: Recommendations for the storage, use and handling of common industrial gases in cylinders (ref 12).

5.3.13 Enclosures should be kept shut during operations if this is required in the manufacturer's instructions. No objects should be allowed in the vicinity of moving parts which could form an obstruction, thus affecting the quality of the product or potentially leading to overheating of components or materials.

5.3.14 Appropriate devices should be in place to ensure the continued running or safe shut down of the equipment in the event of failure of the mains electrical supply.

5.3.15 All equipment, including safety cut out devices, should be installed, used and maintained in accordance with the manufacturer's instructions. Servicing and maintenance should be carried out by a competent engineer.

5.3.16 Electrical installations should be designed, installed and periodically tested by a competent electrician in accordance with the current edition of BS 7671 (the Institution of Electrical Engineers Wiring Regulations) (ref. 13). Inspections should be carried out on a risk assessed basis as recommended in the Periodic Inspection Report.

5.3.17 High level cables should be carried on cable trays or be securely attached to an element of construction, so as not to drop and cause a hazard to firefighters in the event of a fire. Where wiring is run in escape routes, non-metallic clips, ties or trunking should not be used as the sole means of support.

5.3.18 Where the risk assessment indicates that a hazard from static electricity could develop then appropriate earthing and bonding of the printer and any extraneous metal parts should be introduced and regular inspections of the arrangements be undertaken and recorded.

Where a 3D printer is located in a fire compartment provided for that purpose, no combustible materials – whether raw materials, finished products or packaging – should be stored in that compartment

Combustible materials, whether raw materials, finished products or packaging, should not be stored within an area around the process as determined by a risk assessment or as agreed with the insurer

5.4 Location

5.4.1 Wherever possible, any 3D printing equipment that is to operate unattended at any time, or any printer that has been assessed as posing a high fire risk, should be located in a separate fire compartment designed to provide at least 60 minutes fire resistance (integrity and insulation).

5.4.2 Where a 3D printer is located in a fire compartment provided for that purpose, no combustible materials – whether raw materials, finished products or packaging – should be stored in that compartment.

5.4.3 Where a printer is not located in a separate fire compartment, then no stored combustible materials should be located within an area around the process, as determined by a risk assessment or as agreed with the insurer.

5.5 Staff training

5.5.1 Staff using a 3D printer should receive appropriate instruction, including:

- the correct method of using the equipment in accordance with the manufacturer's instructions
- the importance of routine maintenance and the procedures for undertaking and recording this
- the safety features that are incorporated into the equipment and the correct method of setting these for the operation that is to be undertaken
- the maximum period for which printing may be undertaken between checks
- the method for shutting down the equipment safely in an emergency
- the emergency procedures in the event of a fire in either the printer or elsewhere in the compartment in which it is housed
- the mode of operation of the automatic and manual fire protection equipment that is provided

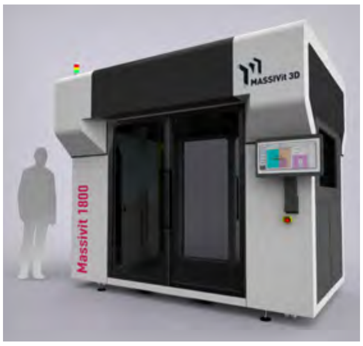

Figure 8: A large scale industrial 3D printer (picture courtesy Massivit 3D/Kitech Design)

5.6 Fire protection

5.6.1 The building in which a 3D printer is installed should be protected by an automatic fire detection and alarm (AFD) system designed, installed and maintained by an engineer with accreditation by an independent UKAS accredited third party certification body. The system should be to a recognised category of installation in accordance with BS 5839-1 (ref 14) as determined by a risk assessment or in consultation with the insurer.

5.6.2 The automatic fire detection and alarm system should be monitored either on-site or by an off-site alarm receiving centre, with accreditation by an independent UKAS accredited third party certification body and operating in accordance with BS 5979 (ref 15). As response times to automatic fire alarm systems can vary, serious consideration should be given to the installation of a fixed fire suppression system if the printer is to run unattended.

5.6.3 The AFD installation should be periodically serviced and maintained by a competent engineer with accreditation by an independent UKAS accredited third party certification body in accordance with BS 5839-1 (ref 14).

5.6.4 The installation of an automatic fixed fire suppression system is strongly recommended if a printer is to run unattended. The installation should be designed to operate within the enclosure or compartment in which the printing is being undertaken. It is important that proving tests are undertaken at the design stage to ensure that the system is suitable and appropriate for the intended application.

FAQ

Can water be used to fight a fire in a 3D printer?

5.6.5 Prior to the design of the fire suppression installation, a risk assessment should be undertaken to identify all conditions that the system must protect against, including idle time, maintenance, routine servicing and cleaning operations.

5.6.6 The fire protection system should be designed following consultation with the insurer. The most appropriate detection and suppression methods should be adopted with the aim of providing effective suppression, while minimising unwanted actuation. The system may incorporate conventional detector heads, video detection techniques, frangible glass bulbs, fusible links or other suitable mechanisms. The fire suppression system should be be designed to operate at the earliest opportunity, while allowing suitable provisions for life safety where necessary.

5.6.7 The most effective extinguishing agent for the application should be selected following a risk assessment, taking into consideration the effectiveness of the agent as well as toxicity, asphyxiation potential, environmental and contamination issues when used with the printing equipment. Dry powder is not generally recommended, as it can cause contamination of electronic control systems and rail or track mechanisms for the printing heads, as well as potentially posing a health hazard in a closed environment. The principal alternatives are carbon dioxide and other gaseous systems.

5.6.8 In small enclosed printers, proprietary fire suppression systems that take the form of a polymer tube linked to a pressurised container of extinguishing medium may be appropriate, as they allow heat to be detected over a wide area, and release the extinguishing agent directly onto the source of heat.

5.6.9 On operation of the fire suppression system, the printer should automatically switch off, and remote signaling be activated in a manned area.

5.6.10 Fixed fire suppression installations should comply with the relevant British Standard (see refs. 16-19). Where there is no appropriate British Standard, best practice, such as the instructions issued by the manufacturer or supplier of the printer, should be followed.

5.6.11 Fixed fire suppression systems should be designed, installed and commissioned by an engineer certificated by an independent UKAS accredited third party certification body, in compliance with the requirements of national or other recognised standards.

5.6.12 The risk assessment and business impact analysis may indicate that an automatic sprinkler installation may be appropriate. Sprinkler systems should be designed, installed, commissioned and maintained in accordance with the LPC Sprinkler Rules incorporating BS EN 12845 (ref 20), by engineers having accreditation by an independent UKAS accredited third party certification body.

5.6.13 Suppression systems should be tested and maintained according to the requirements of the relevant British Standard and/or the installer's recommendations, by a competent engineer with accreditation by an independent UKAS accredited third party certification body. Suitable records should be kept.

5.6.14 Arrangements should be in place for the prompt recommissioning of an automatic fire suppression system that has actuated. Back up supplies of extinguishing agents should be kept or arrangements made for their immediate replacement.

5.6.15 Following actuation of the fire suppression system, the printer should not be left working unattended until:

- the automatic fire suppression system has been fully recommissioned
- the printer has been inspected and found to be serviceable by a competent person
- appropriate repairs have been undertaken or replacement parts fitted by a competent person to render the printer serviceable

5.6.16 In addition to the automatic suppression systems, a suitable number of appropriate portable fire extinguishers should be available and immediately accessible in the case of a fire. The provision of dry powder extinguishers should be avoided (see 5.6.7). Portable extinguishers should be approved and certified by an independent, third party certification body, be installed in accordance with BS 5306-8 (ref 21), and inspected and maintained in compliance with BS 5306-3 (ref 22).

5.6.17 Where large 3D printers are in operation, or there are printers that have been identified as posing a high fire risk, information should be provided for the fire and rescue service at a prominent location (often in a box provided for this purpose outside the main entrance) to indicate:

- the layout of the building
- the location of large or hazardous 3D printers and any other unattended processes
- the location of emergency shutdown points for the printers
- the nature of the automatic fire suppression system(s) and the location of any controls
- the location and quantity of any hazardous materials
- contact details for specialist staff who may need to be consulted
- the location of hydrants, rising mains or other sources of water for firefighting purposes

6 Checklist

		Yes	No	N/A	Action required	Due date	Sign on completion
6.1	**Compliance with fire safey legislation (section 5.1)**						
6.1.1	Has a suitable and sufficient fire risk assessment been undertaken for all premises to which the Regulatory Reform (Fire Safety) Order 2005 (or equivalent legislation in Scotland and Northern Ireland) applies? (5.1.1)						
6.1.2	Has an assessment of the processes been undertaken in accordance with the requirements of the Dangerous Substances and Explosive Atmospheres Regulations (as amended 2015)?						
6.1.3	Are risk assessments subject to periodic review, including at the time when any changes to the machinery, plant or materials being employed in the printing process or in the layout of the workplace are being considered? (5.1.2)						
6.2	**Business continuity (Section 5.2)**						
6.2.1	Is the 3D printing process carefully managed to avoid unnecessary disruption to the efficient functioning of the business? (5.2.1)						
6.2.2	Is the computer software, CAD or 3D modelling files that drive the printers duplicated off site together with other company records so that the electronic instructions for the printers are not lost in the event of fire? (5.2.2)						
6.2.3	Does the emergency plan address the implications of a fire, flood or other perceived disaster on all facets of the business model and indicate the lines of communication that should be followed, the contact details for specialist assistance, providers of alternative accommodation and suppliers of replacement 3D printing and other equipment? (5.2.3)						
6.2.4	Are tabletop exercises held periodically to test the effectiveness and suitability of the emergency plan? (5.2.4)						
6.2.5	Has consideration been given to applying commercially available computer programs, such as the ROBUST software or a similar product to develop and check the adequacy of the plan? (5.2.5)						
6.2.6	Where parts are purchased that are known to be produced by 3D printing then does the organisation's emergency plan identify alternative suppliers? (5.2.6)						
6.3	**Fire safety management (Section 5.3)**						
6.3.1	Is care taken when considering purchasing 3D printing facilities that the most appropriate equipment is purchased and the way that the equipment operates and the facilities that need to be provided are fully understood? (5.3.1)						
6.3.2	Are any areas of heat production in the process identified to allow safety controls, including thermostats and upper temperature limit temperature sensors to be identified and put in place? (5.3.2)						

		Yes	No	N/A	Action required	Due date	Sign on completion
6.3.3	Has the fire safety manager referred to the relevant fire and rescue service to become aware of the level of response in the area in which their premises are located and considered this when undertaking and reviewing the fire risk assessments? (5.3.3)						
6.3.4	Are site plans available for the emergency services showing the locations of the printing equipment, associated installations and other fire hazards? (5.3.4)						
6.3.5	Before being left unattended, is a new 3D printing process fully developed and run for a prolonged period with staff in attendance? (5.3.5)						
6.3.6	If equipment is left operating wihthout staff in attendance, has a specific risk assessment for the process been undertaken and appropriate control measures introduced in line with the recommendations in RC42? (5.3.6)						
6.3.7	Where equipment is left to run unattended are notices displayed prominently outside the door(s) to the compartment in which the process is located giving the contact details of staff who should be contacted in an emergency? (5.3.7)						
6.3.8	Does the fire risk assessment undertaken during the planning stage consider the nature of the materials used in the process and identify any powders, flammable liquids or other hazardous materials to allow suitable measures to be adopted for their safe storage, handling and use? (5.3.8)						
6.3.9	Where powders are used in the process as a powder bed or a support material does the guidance presented in RC12 being observed? (5.3.9)						
6.3.10	Are the recommendations set out in RC55 observed where flammable or highly flammable materials are in use? (5.3.10)						
6.3.11	Is the use of flammable liquids avoided wherever possible? Where this is unavoidable as part of a process or for servicing and maintenance purposes, are the minimum quantities in the building consistent with effective working? (5.3.10)						
6.3.12	Are appropriate measures and materials in place to address a spillage of flammable liquid? (5.3.11)						
6.3.13	Where 3D printing processes are carried out in controlled atmospheres are measures for monitoring and controlling the gas supply and composition of the atmosphere planned and put in place? (5.3.12)						
6.3.14	Is the storage, use and handling of gases in cylinders being undertaken in accordance with the recommendations in RC8? (5.3.12)						
6.3.15	Are printing enclosures kept shut during operations if this is required in the manufacturer's instructions? (5.3.13)						
6.3.16	Are appropriate devices in place to ensure the continued running or safe shut down of the equipment in the event of failure of the mains electrical supply? (5.3.14)						
6.3.17	Is all equipment, including safety cut out devices, installed, used and maintained in accordance with the manufacturer's instructions with servicing and maintenance carried out by a competent engineer? (5.3.15)						

		Yes	No	N/A	Action required	Due date	Sign on completion
6.3.18	Are electrical installations designed, installed and periodically tested by a competent electrician in accordance with the current edition of BS 7671 with inspections carried out on a risk assessed basis as recommended in the Periodic Inspection Report? (5.3.16)						
6.3.19	Are high level cables carried on cable trays or securely attached to an element of construction so as not to drop and cause a hazard to firefighters in the event of a fire? (5.3.17)						
6.3.20	Where the risk assessment indicates that a hazard from static electricity could develop then has appropriate earthing and bonding of the printer and any extraneous metal parts been introduced and regular inspections of the arrangements been undertaken and recorded? (5.3.18)						
6.4	**Location (Section 5.4)**						
6.4.1	Wherever possible, is any 3D printing equipment that is to operate unattended at any time or any printer that has been assessed as posing a high fire risk located in a separate fire compartment designed to provide at least 60 minutes fire resistance? (5.4.1)						
6.4.2	Where a 3D printer is located in a fire compartment provided for that purpose, is the compartment clear of combustible materials, including raw materials, finished products and packaging? (5.4.2)						
6.4.3	Where a printer is not located in a separate fire compartment is an area around the process as determined by risk assessment or as agreed with the insurer clear of stored combustible materials? (5.4.3)						
6.5	**Staff training (Section 5.5)**						
6.5.1	Do staff using a 3D printer receive appropriate instruction? (5.5.1)						
6.6	**Fire protection (Section 5.6)**						
6.6.1	Is the building in which a 3D printer is installed protected by an automatic fire detection and alarm system designed, installed and maintained by an engineer with accreditation by an independent UKAS accredited third party certification body? (5.6.1)						
6.6.2	Is the automatic fire detection and alarm system monitored either on-site or by an off-site alarm receiving centre? (5.6.2)						
6.6.3	Is the AFD installation periodically serviced and maintained by a competent engineer? (5.6.3)						
6.6.4	Has the installation of an automatic fixed fire suppression system designed to operate within the enclosure or compartment in which the printing is being undertaken been considered if a printer is to run unattended? (5.6.4)						
6.6.5	If a fire suppression installation is being considered is a risk assessment to be undertaken to identify all conditions that the system must protect against, including idle time, maintenance, routine servicing and cleaning operations? (5.6.5)						

		Yes	No	N/A	Action required	Due date	Sign on completion
6.6.6	If a fire suppression installation is being considered is it to be designed in conjunction with the insurer to minimise the likelihood of an unwanted actuation? (5.6.6)						
6.6.7	Has the most effective extinguishing agent for the application been selected following a risk assessment taking into consideration the effectiveness of the agent as well as toxicity, asphyxiation potential, environmental and contamination issues when used with the printing equipment? (5.6.7)						
6.6.8	In small enclosed printers, has consideration been given to proprietary fire suppression systems that take the form of a polymer tube linked to a pressurised container of extinguishing medium as these may apply the extinguishing agent directly onto the source of heat? (5.6.8)						
6.6.9	On operation of the fire suppression system, will the printer automatically switch off and remote signaling be activated in a manned area? (5.6.9)						
6.6.10	Do fixed fire suppression installations comply with the relevant British Standard, or where there is no appropriate British Standard, do they comply with best practice, such as the instructions issued by the manufacturer or supplier of the printer? (5.6.10)						
6.6.11	Are fixed fire suppression systems designed, installed and commissioned by an engineer certificated by an independent UKAS accredited third party certification body in compliance with the requirements of national or other recognised standards? (5.6.11)						
6.6.12	In large areas or where there is no significant hazard from the use of flammable liquids or exposed electrical installations has the risk assessment indicated that a water sprinkler installation may be appropriate? (5.6.12)						
6.6.13	Are suppression systems tested and maintained according to the requirements of the relevant British Standard and/or the installer's recommendations by a competent engineer with accreditation by an independent UKAS accredited third party certification body? (5.6.13)						
6.6.14	Are arrangements in place for the prompt recommissioning of an automatic fire suppression system that has actuated? (5.6.14)						
6.6.15	Following actuation of a fire suppression system, is the printer only operated with staff in attendance until the automatic fire suppression system has been fully recommissioned, the printer has been inspected and found to be serviceable by a competent person or repairs have been made by a competent person to render the printer serviceable? (5.6.15)						
6.6.16	In addition to the automatic suppression systems, is a suitable number of appropriate portable fire extinguishers available and immediately accessible in the case of a fire? (5.6.16)						
6.6.17	Where large 3D printers are in operation or there are printers that have been identified as posing a high fire risk is information provided for the fire and rescue service at a prominent location? (5.6.17)						

7 References

1. Regulatory Reform (Fire Safety) Order 2005, SI 2005 No 1541, The Stationery Office.
2. The Fire (Scotland) Act 2005, asp 5, The Stationery Office.
3. Fire Safety (Scotland) Regulations 2006, Scottish SI 2006 No 456, The Stationery Office.
4. Fire and Rescue Services (Northern Ireland) Order 2006, SI 2006 No 1254 (NI9), The Stationery Office.
5. Fire Safety Regulations (Northern Ireland) 2010, SI 2010 No 325 (NI), The Stationery Office.
6. Dangerous Substances and Explosive Atmospheres Regulations (DSEAR), 2002, SI 2002 No 2776 (as amended in 2015), The Stationery Office.
7. *Business resilience: A guide to protecting your business and its people*, 2005, Fire Protection Association.
8. The ROBUST software (Resilient Business Software Toolkit) may be found at https:// robust.riscauthority.co.uk
9. RC42: *Recommendations for fire safety of unattended processes*, 2011, Fire Protection Association.
10. RC12: *Recommendations for the prevention and control of dust explosions*, 2015, Fire Protection Association.
11. RC55: *Recommendations for fire safety in the storage, handling and use of flammable and highly flammable liquids*, 2014, Fire Protection Association.
12. RC8: *Recommendations for the storage, use and handling of common industrial gases in cylinders*, 2016, Fire Protection Association.
13. BS 7671: 2008 +A3 2015: *Requirements for electrical installations, IET Wiring Regulations)*, British Standards Institution.
14. BS 5839: *Fire detection and fire alarm systems for buildings: Part 1: 2017: Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises*, British Standards Institution.
15. BS 5979: 2007: *Remote centres receiving signals from fire and security systems. Code of practice*, British Standards Institution.
16. BS 5306: Part 0: 2011, *Fixed firefighting systems. Foam systems. Design, construction and maintenance*, British Standards Institution.
17. BS 5306: Part 4: 2001 + A1 2012, *Fire extinguishing installations and equipment on premises. Specification for carbon dioxide systems*, British Standards Institution.
18. BS EN 13565-2: 2009, *Fixed firefighting systems. Foam systems. Design, construction and maintenance.* British Standards Institution
19. BS EN 12416-2: 2001, *Fixed firefighting systems. Powder systems. Design, construction and maintenance.* British Standards Institution.
20. *LPC Rules for automatic sprinkler installations incorporating BS EN 12845: (Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance, British Standards Institution)*, 2015, Fire Protection Association.
21. BS 5306-8: 2012: *Fire extinguishing installations and equipment on premises. Selection and positioning of portable fire extinguishers. Code of practice.* British Standards Institution.
22. BS 5306-3: 2017: *Fire extinguishing installations and equipment on premises. Commissioning and maintenance of portable fire extinguishers. Code of practice*, British Standards Institution.

8 Further reading

- Additive manufacturing technology standards: a number of documents with various designations. www.astm.org/Standards/additive-manufacturing-technology-standards.html administered by

Fire Protection Association
London Road
Moreton in Marsh
Gloucestershire GL56 0RH
Tel: +44 (0)1608 812500
Email: info@riscauthority.co.uk
Website: www.riscauthority.co.uk

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